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LATEST CIVILIAN V/STOL AIRCRAFT PROJECTS OF HAWKER SIDDELEY AVIATION

(Continuation from FR6/71)

T. K. Szlenkier

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LATEST CIVILIAN V/STOL AIRCRAFT PROJECTS OF HAWKER SIDDELEY AVIATION

(Continuation from FR6/71) *

T. K. Szlenkier**

ABSTRACT. The latest civilian V/STOL aircraft are examined. It is found that such aircraft are more economical and convenient in short air flights, require lower capital investments compared with other systems, and have less influence on the environment.

CONCLUSION OF PART ONE

Only a relatively simple flap for which the air stream came from the inside was investigated by HSA in the year 1970. The area loading for the /35*** design was 390 kg/m^2, and a take-off distance of 600m is required. The installed thrust/weight ratio is 0.4 and the by-pass ratio of the forward engines is 3.0. The aircraft weight, initial costs and direct operational costs were greater than for STOL aircraft having fan-lift engines.

PART TWO: MECHANICAL FLAPS

The STOL aircraft with mechanical flaps according to Figure 19* has four forward engines with a high by-pass ratio. These engines are derived from the Rolls-Royce RB 410. A gas generator, developed from the M 45 H powers a blower having a reversed blade inclination and a by-pass ratio of almost ten through a gear. In order to install such large engines under the wing, a shoulder covering arrangement is necessary.

*Translator's note: Part I available in English as NASA TTF 14,619

**Hawker Siddeley Aviation Ltd.

***Numbers in the margin indicate pagination in the original foreign text.

In this design, the effects of the jet flaps with air coming from the outside were intentionally avoided and the engines were suspended from long posts, in order to have predictable and conventional handling characteristics in case an engine failed. If the outer jet flap effect is taken advantage of to its fullest extent, there are large changes in the lift distribution along the wing if an engine fails. This requires very complicated control systems in order to satisfy the aircraft handling requirements.

In order to obtain a high lift, an almost straight wing with a high aspect ratio is used, which has wing loading during take-off of only 320 kg/m^2. The wing has an extendable forward wing, slotted Fowler flaps and a crossed directional rudder. The maximum velocity characteristics are limited in this design, and the cruise Mach number is limited to 0.70. However, because of the selected " engines" with the large by-pass ratio and the reversible blowers, it would not be possible to have a velocity which is much higher.

The design has the advantages of improved flight path control and thrust braking. However, there are restrictions due to blower strength and blade profile.

Although the design with mechanical flaps has the advantage of simplicity, the large weight of the large wings and the reduced productivity due to the limited cruise velocity bring about an increase in the indirect operational costs amounting to 10%, compared with the aircraft having four lifting engines.

SUMMARY

The first investigations on jet propelled STOL aircraft, which were terminated in 1970, showed that aircraft having fan lift engines were superior with respect to economy of operation compared with solutions having mechanical flap systems and central flaps in which the air comes from the inside. Compared with the aircraft having mechanical flaps, the direct operational costs are about 10% lower, and compared with the aircraft having flaps from which the air comes from the inside, they are about 4% lower. Neverthless, it is necessary to perform additional investigations of complicated flap systems, because such designs could be more economical compared with the simpler systems.

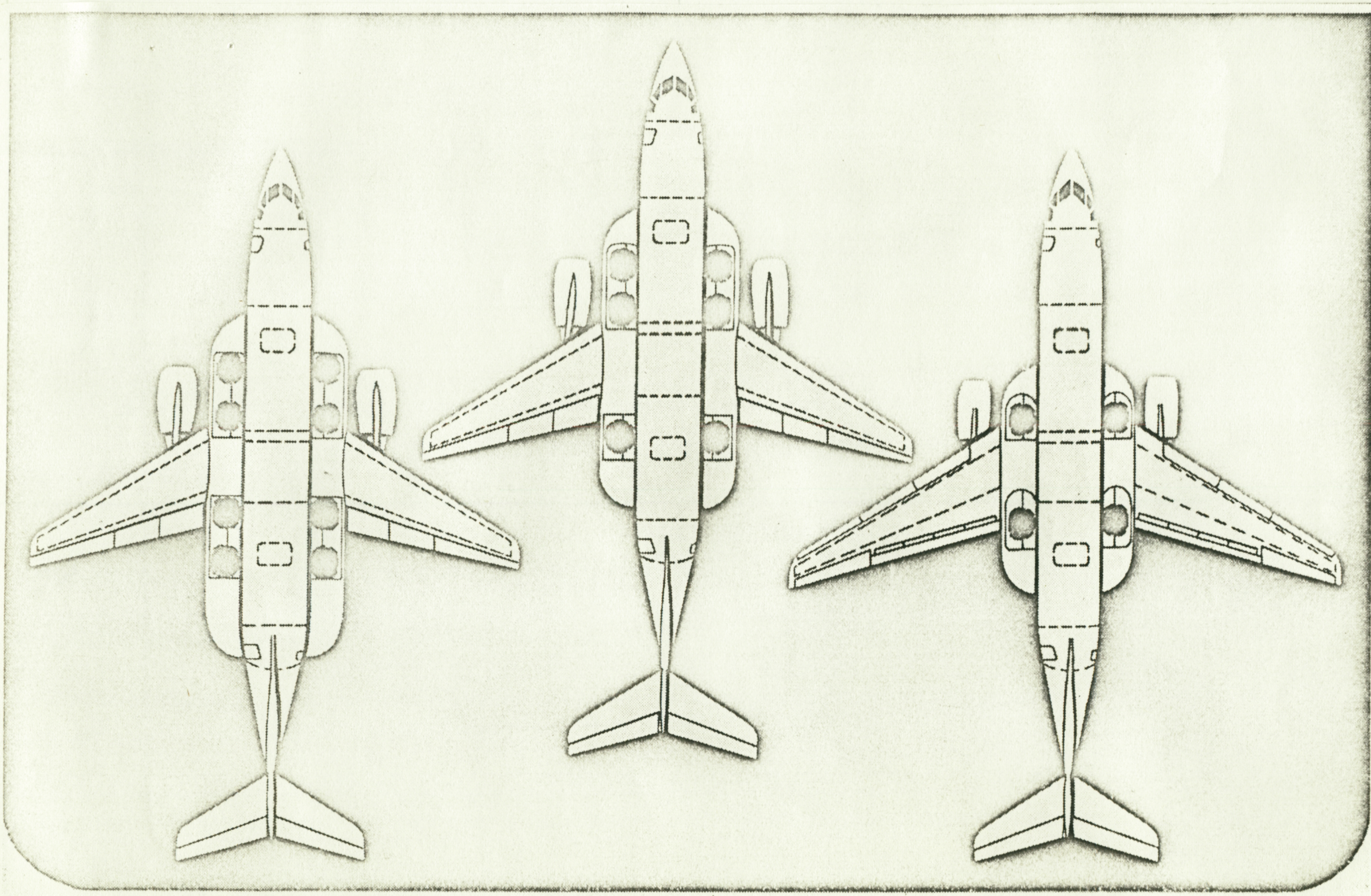

Fig. 20: STOL-Variants having lifting engines.

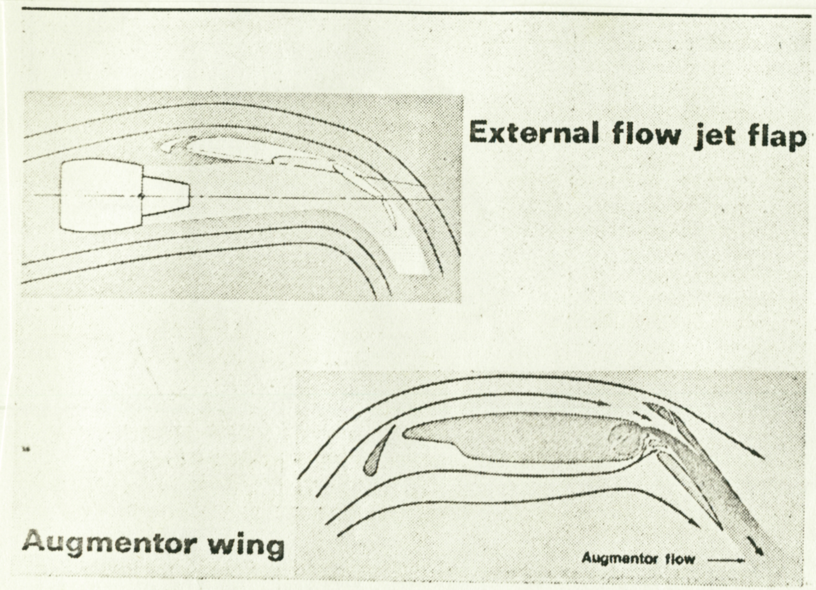

Fig. 21: Jet flap cross-sections.

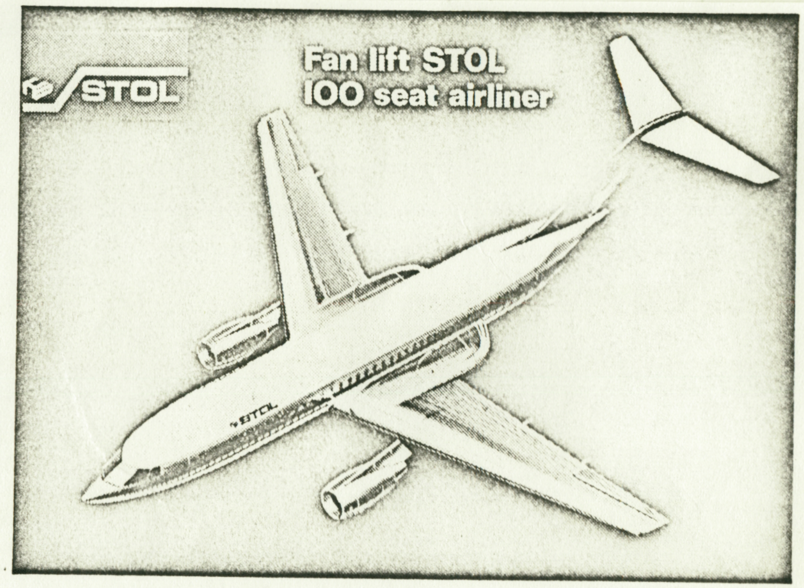

Fig. 22: STOL-Commercial aircraft study 147 with fan-lift engines.

The aircraft with lifting engines have a number of other advantages, which will be considered later on. There are indications that the STOL aircraft with lifting engines, as suggested in 1970, can be improved even further. These indications led to the present STOL suggestion, which will be discussed in the next paragraph.

6. STOL COMMERCIAL AIRCRAFT WITH FAN JET ENGINES, DESIGN STUDY NO. 147 (1971).

6.1 General Description

For some time it has been known (see also Section 4.6), that jet interaction during forward flight are not the same for all engines because of the lifting engines located in the pods, such as in the HS141-16 or the STOL aircraft according to Figure 19. Instead, this depends on the position /36 of the engines in front of or behind the wing. In general there is a loss in lift if the engines are located ahead of the wing, and there is an increase in the lift if they are located behind the wing. The order of magnitude of this effect decreases as the distance of the wing increases. Model experiments of the STOL aircraft mentioned above in the Rolls-Royce RB 410 of HSA showed (Figure 7) the aerodynamic effect of jet interaction is more advantageous for lifting engines located at the rear than could be expected.

For these reasons, a design was assumed (Study No. 147), as shown in Figure 22. This aircraft has only two lifting engines in half pods behind the wing. Because of the necessity of trimming the pitch moments produced /37 by the lifting engines located behind the center of gravity by raising the tail, it is not possible to obtain the entire gain caused by interference. Nevertheless, a valuable improvement is obtained in comparison with earlier STOL designs with lifting engines .

The Study 147 STOL aircraft satisfies the requirements in Table 2 and Table 3, except that the descent rate during approach was increased. The aircraft design is conventional except for the small half pods. One lifting engine is installed in each of these pods. Other characteristic features are the fact that the wings have a low position and the forward engines are installed in a manner similar to the HS 141-16 or HS 141-12 V/STOL projects.

The two RB 202-36 lifting engines are similar to those of the V/STOL

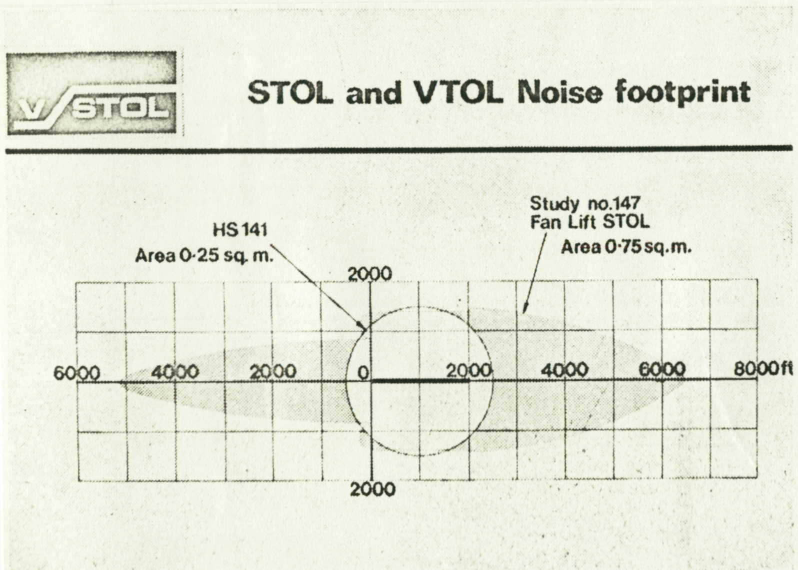

Fig. 24: 90 PNdb Noise zones for STOL and VTOL.

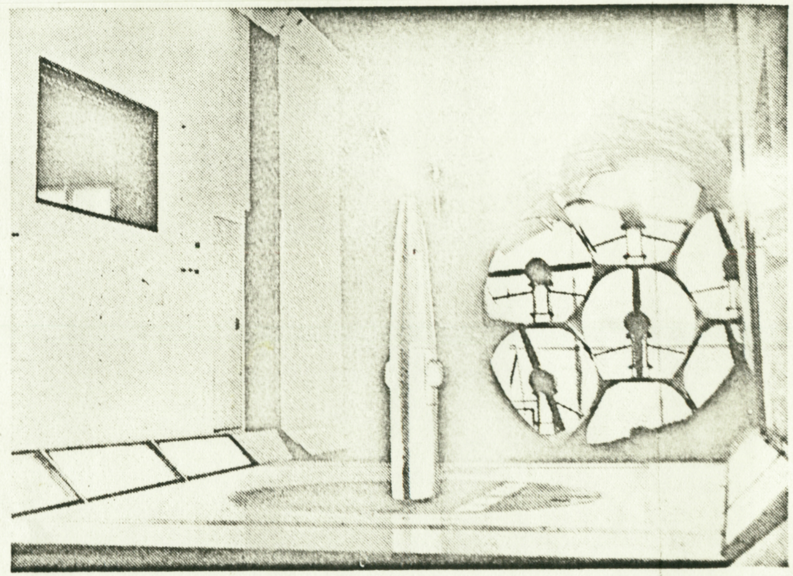

Fig. 25: V/STOL Wind-tunnel at the HSA in Hatfield.

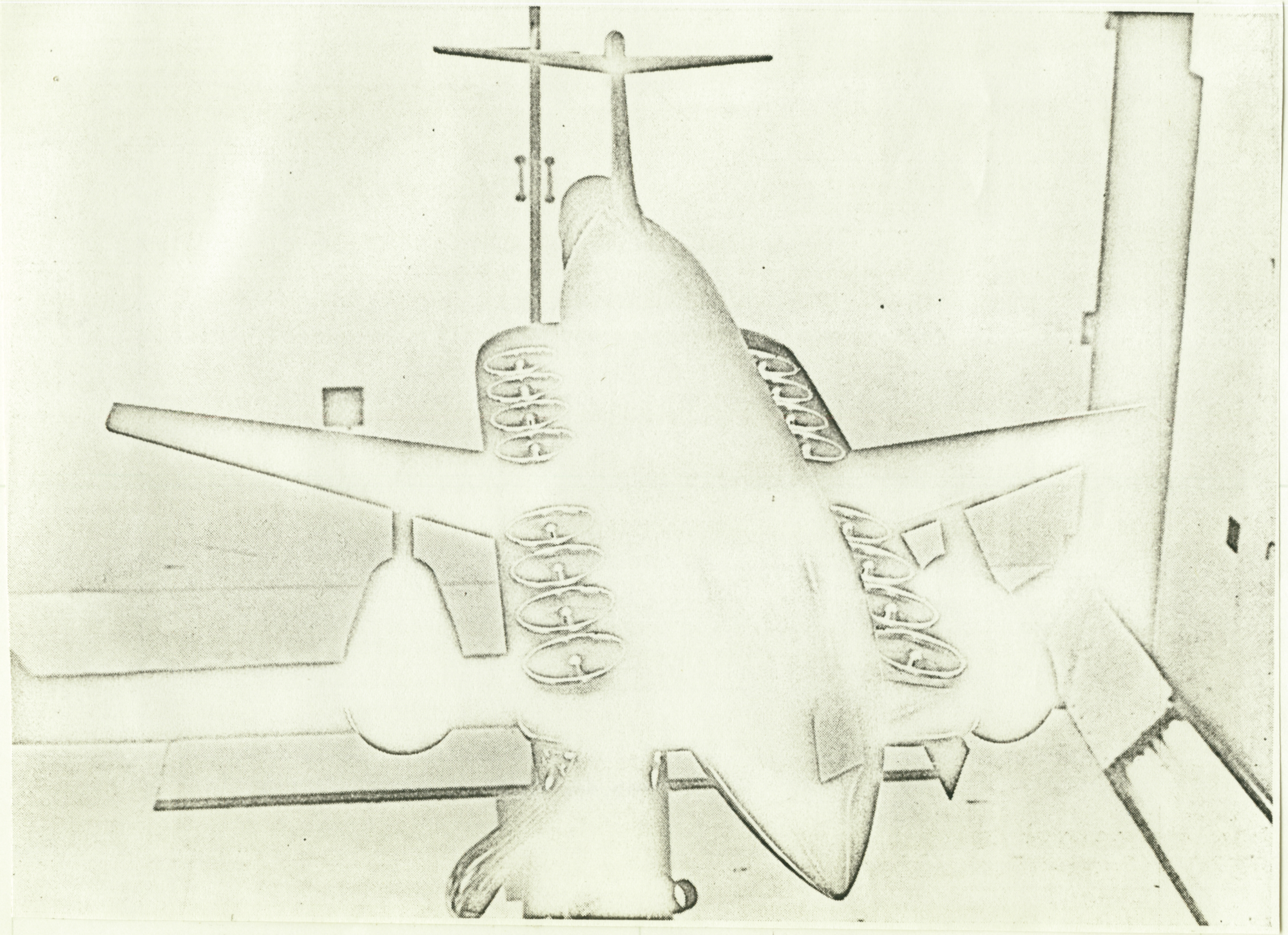

Fig. 26: Model of the HS 141-16 with deployed lift-fans.

projects. However, they belong to an earlier construction series and have a lower thrust/weight ratio. The lifting engine installation is similar to that of the HS 141-16. However, the deflection range was increased in order to increase the relative lifting thrust contribution during the accelerating and braking phases of STOL operation. Quiet "engines" are located under the wing. Outer jet flap effects are avoided by means of relatively long supports. The design cruise Mach number is 0.75. The high lift devices consist of forward wings which can be extended over the entire span as well as large slotted mechanical Fowler flaps. /38

The control around the yaw axis is done by means of a rudder and perforated spoilers in front of the flaps. If there is a failure in the lifting engines, trimming can be done with the rudders alone, and there will still be available sufficient reserves for control around the roll axis. If the forward engines fail, a double hinge side rudder can be used to compensate for it. The design also can withstand 25 knot cross-wind components.

The fuselage has the comfort level of coach class and there are five seats next to each other. One hundred passengers can be seated with a seat distance of 34 inches. The baggage is located in two compartments below the floor, and there is good accessibility from the side.

6.2 WEIGHTS AND PERFORMANCES.

In order to transport 100 passengers (9100 kg payload) over two distance segments of 370 km each, the STOL design take-off weight is 52600 kg. The operational empty weight is 36,300 kg. The 2x270 flight distance assumed in the design was performed at a cruise Mach number of 0.75 at an altitude of 6100 m. This corresponds to a velocity of 850 km/h. The distance without intermediate landing corresponding to this is 980 km. The range with full payload can be increase to 1090 km, if long distance performance is assumed. Because of the increased take-off weight from airfields with a length of 750 m, the range can be increased up to 2400 km. The maximum inclination angle after take-off is 17.5° and the approach angle is 7.5° during landing.

6.3 NOISE LEVEL

Due to the noise development of the RB 202-31 lifting engines and the

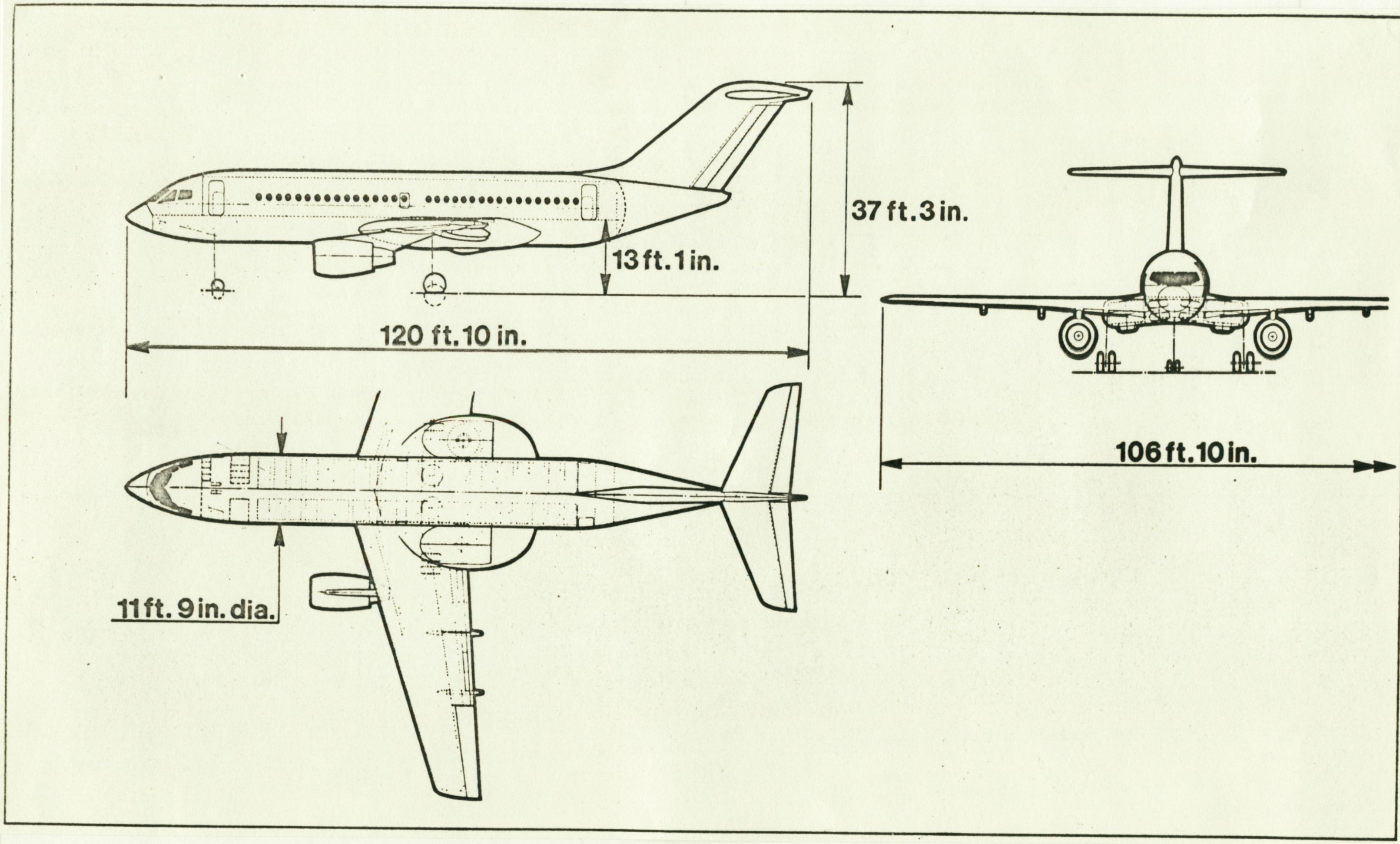

Fig. 23: Views from three sides of the aircraft according to study 147.

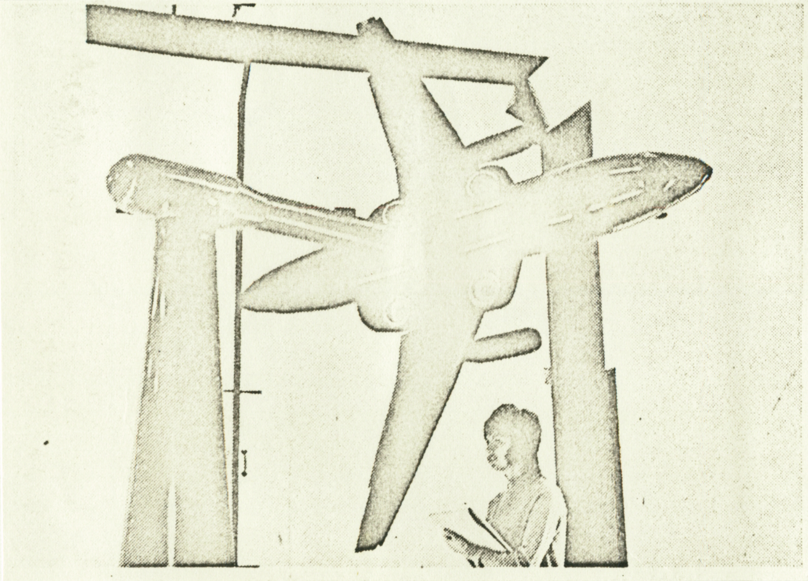

Fig. 27: STOL aircraft with thrust ejectors.

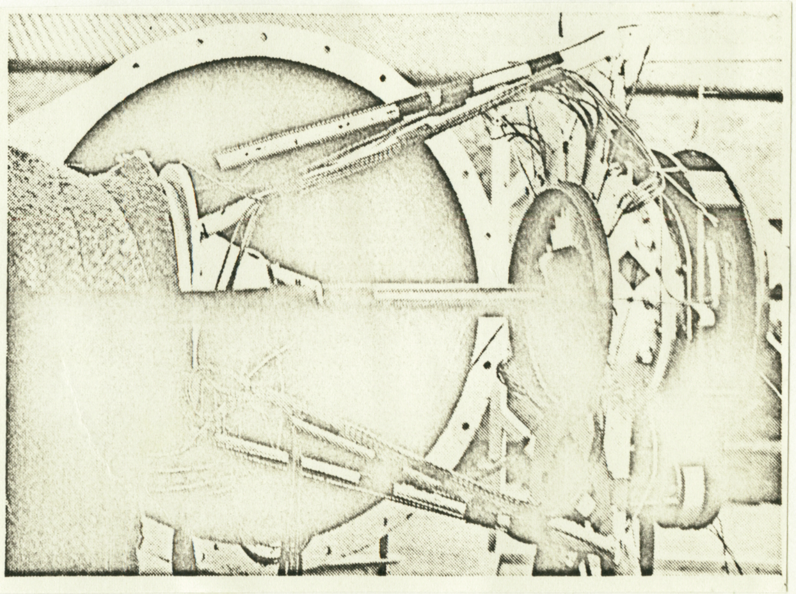

Fig. 28: 30 cm blower for noise and installation studies.

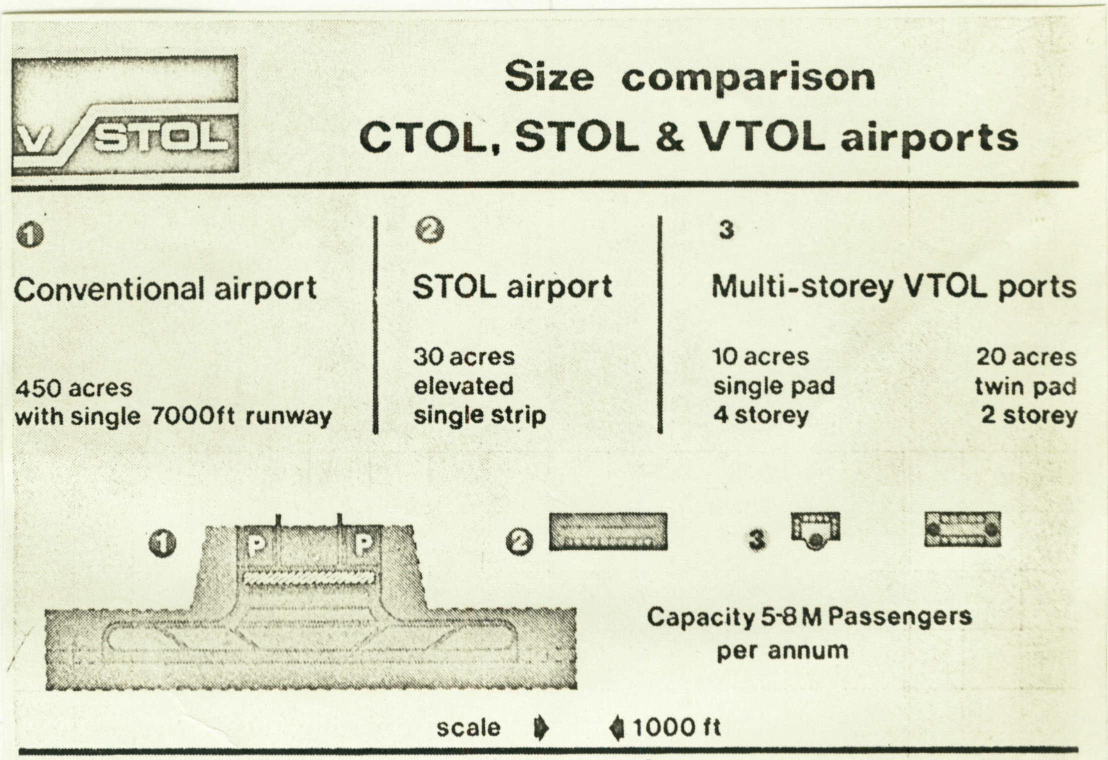

Fig. 30: Comparison of the airport sizes for CTOL, STOL and VTOL.

quiet forward engines, the length of the 90 PNdb sound ellipse on the ground is 3540 m, and its area is almost two square kilometers (see Figure 24). The absorption of the noise by the ground was considered in these estimates. /43

6.4 SAFETY AND COMFORT LEVEL

Safety of operation of the STOL aircraft with fan jet engines is provided due to the fact that it was designed according to specifications of aviation boards such as the ARB, LBA, FAA. Special care must be given to the engine performance requirement. However, there are other STOL solutions in which the engines make a contribution to the aerodynamic lift.

In order to operate from airports only 600 m long, relatively high accelerations are required. The peak values for operation, however, are only relatively higher than for the values specified for take-off and landing of the Hawker Siddeley Trident. The pitch positions and rotational rates

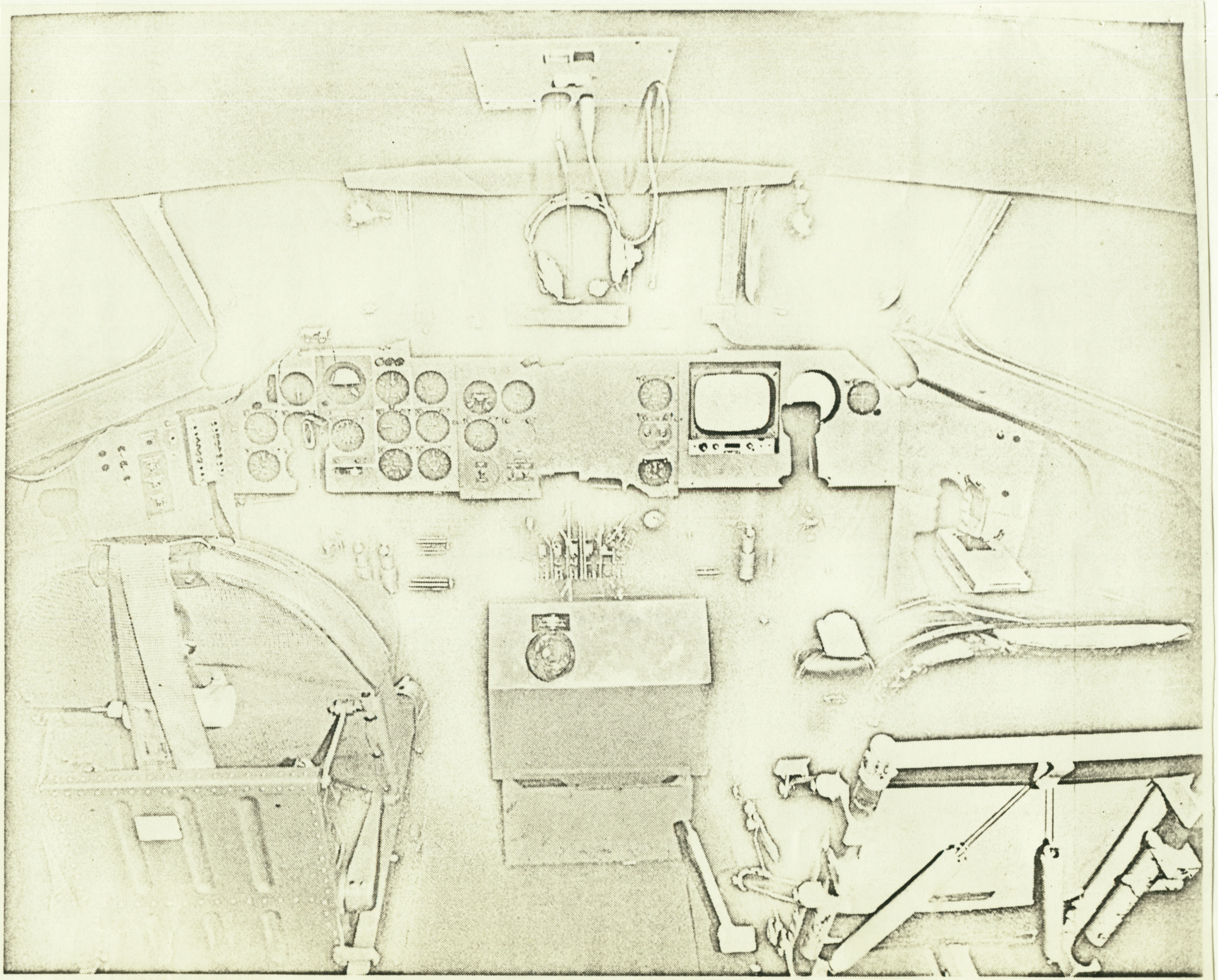

Fig. 29: Flight simulator at Hawker Siddeley Aviation in Hatfield.

are also comparable. Therefore, it seems that the planned acceleration and pitch position characteristics are quite acceptable for this STOL aircraft. Otherwise, passenger comfort is comparable with that of conventional jet aircraft, because no design compromises are required with aircraft having lifting engines. /44

6.5 COMPARISONS WITH OTHER STOL DESIGNS

According to investigations of HSA, the direct operational costs of the aircraft according to Study 147 are about 15% below those of the best designs with mechanical flaps. Investigations of complicated jet flap designs are still incomplete; however, it is believed that the aircraft with lifting engines will be more economical, because the design is hardly restricted by STOL flight performance requirements.

The promising STOL designs also have four engines. This is why the ratios of effective installed thrust to weight are comparable. However, in the aircraft with fan jet engines, the thrust contribution of the lifting engines, (40% of the total thrust) is coupled with the low engine weight, low drag and low costs. Other advantages of this design include the following: /45

1. It is expected that it will be easier to satisfy the prescribed noise restrictions than with jet flap aircraft. According to investigations of NASA (SP-259), considerable difficulties with noise can occur. In the case where the flaps receive the air from the outside, the noise production of the exhaust jet/flap impingement still represents an unknown. This is also the case for the wing slot nozzle when the flap receives the air from the inside. The latter operates at a pressure ratio higher than 1.4.
2. In order to reduce the technical risk, only the aerodynamic high lift aids were used which correspond to todays' technology.
3. The lower wing design can be retained, which is more advantageous for supplying the aircraft on the ground.
4. Only two forward engines are required. The short take-off distance requires no compromise either in the size or in the installation methods.
5. The lift can be controlled by thrust modulation of the lifting engines.
6. STOL as well as V/STOL aircraft with lifting engines have many characteristic features. STOL aircraft with lifting engines could be introduced as predecessors

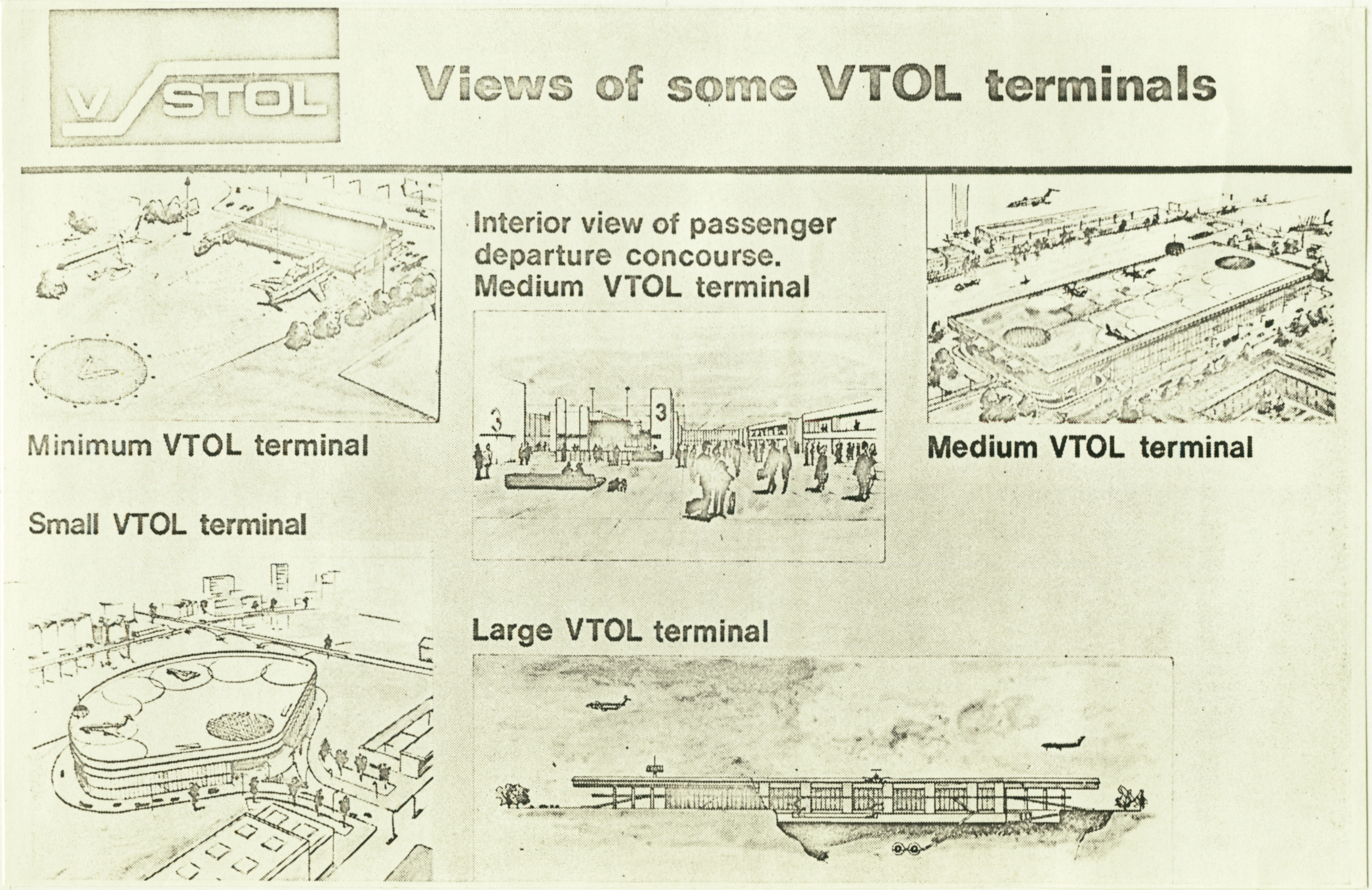

Fig. 31: Some Vertiports.

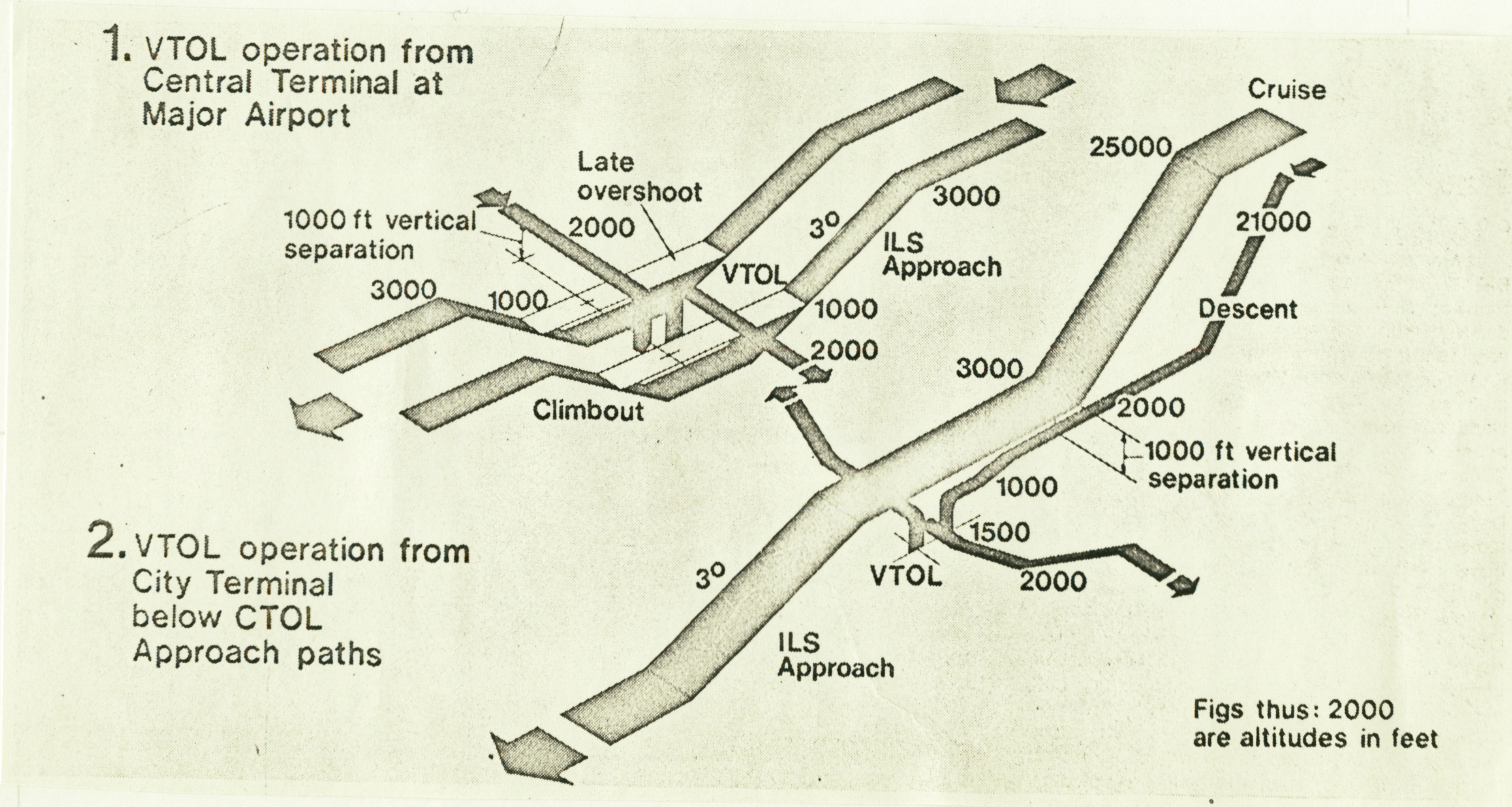

Fig. 32: Separation of air traffic by VTOL

for V/STOL aircraft with lifting engines.

7. RESEARCH AND DEVELOPMENT

The investigations of the most modern V/STOL aircraft are being supported by research programs, in which the V/STOL windtunnel at Hatfield (Figure 25) is being used. A number of realistic aircraft models are being measured. The sixteen lifting engines on the model of the HS 141-16, each having a diameter of 15 cm, are operated with compressed air (Figure 26). The STOL model with lifting engines (Figure 27), which is being tested in the same wind tunnel, has four 10 cm diameter ejectors to simulate the lifting engines. Other models have been tested in the high velocity and extremely low velocity wind tunnels in Hatfield, in order to determine the conventional aircraft characteristics and to obtain an estimate of the effectiveness of the high lift devices.

In addition to the wind tunnels, there are experimental set-ups which have been built, in order to determine the static jet interferences and the noise. A 30 cm diameter blower, operated by an air turbine, simulates the RB 202 fan. It is used for noise measurements under the most varied conditions, in order to determine the effect of its installation on the cross-wind, i.e. (see Figure 28).

Flight performance and contol problems as well as aircraft control near the airport are being investigated in Hatfield in a flight simulator (Figure 29). The simulator is now being modified in order to obtain a moveable flight deck area, a digital computer and an improved visual representation. Over thirty test pilots of HSA, of the RAE, of the Dornier AG, of the BEA and of the KLM have participated in the evaluation of the HS 141. Close cooperation exists with the Royal Aircraft Establishment in Farnborough and Bedford, where research programs complement those of HSA in many ways. In spite of these activities, there is a pressing need for tests and conventional development, which can only be performed on a full scale operational device. This problem can no longer be delayed, if additional advances in the area of modern civilian V/STOL and STOL profects are desired.

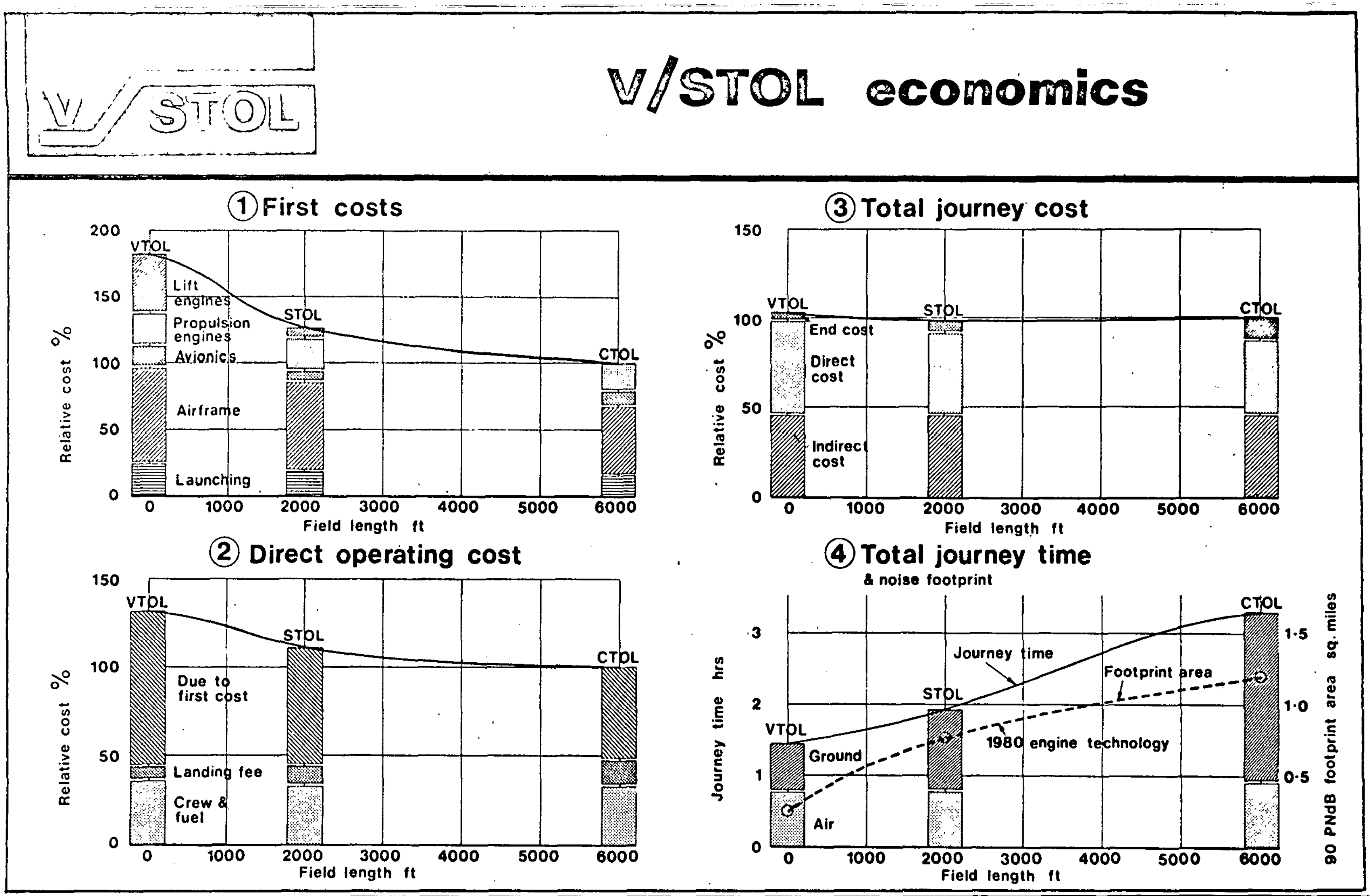

Fig. 33: Economy calculations of VTOL.

8. SOME APPLICATION CONSIDERATIONS

A comparison of CTOL, STOL and V/STOL aircraft (see Figure 30), which all have the same capacity, showed that a great deal of space can be saved by STOL and V/STOL systems. As Figure 24 already shows, the 90 PNdb noise zone is considerably smaller for a 100 seat V/STOL aircraft with new technology engines than for a STOL aircraft with a 600 m landing field. Nevertheless, we may argue that a noise zone at the 90PNdb limit for STOL operation and having a size of about 2 km^2 can be found in most large cities, either near ports or over large railroad freight yards.

Figure 31 shows VTOL airports of various capacities. The largest one is obtained by modification of a STOL aircraft having a single 600 m runway, which, however, would have limited capacity for STOL operation. Therefore, if an STOL system is to be the predecessor to the VTOL system, an infrastructure would be available which would provide a large increasing capacity when VTOL operation is introduced later on. This increasing capacity can also be tolerated by the flight controllers, because VTOL has a greater flexibility due to the additional approach and landing paths (i.e., the operation is greatly independent of wind direction and turbulence). This leads to a better efficiency in the use of the air space. Figure 32 shows the separation of the various aircraft traffic types, which can be obtained by VTOL operation.

9. V/STOL ECONOMY

The economic advantages of V/STOL are summarized in Figure 33. Here it is shown that the relatively high procurement costs of the STOL and VTOL aircraft are equalized by the increased productivity, which reduces the direct operational costs. These come about by time savings during take-off and landing, as well as on the ground because of the reduced taxiing distances. /46
If the same indirect operational costs are assumed as for conventional aircraft operation, the total operational costs (direct and indirect) are only slightly above those for CTOL. If we also include the low costs for arrival and departure to and from the airport, one finds that the total costs are almost the same for all systems. However, VTOL and STOL offer considerable time savings. Considering the fact that the noise zone for STOL is larger

Fig. 34: V/STOL aircraft with lifting engines above a Vertiport in a large city.

than for VTOL (see Figures 24 and 33), it can be assumed that STOL airports will have to be located farther away from points where the demand exists than Vertiports. This explains the further reduction in the travel time on the ground in the favor of V/STOL. Nevertheless, even the small time savings for STOL are considerable. If we now assume that "time is money", and we assume that the average traveler will account for his time at a rate of about 10.0 DM per hour (of course the rate would have to be higher for businessmen), effective total travel costs could be defined which, for a distance of 560 km, would be about 10% lower for V/STOL and about 5% lower for STOL than for CTOL. These estimates do not even consider the delays caused by the over-filled air space and the associated higher costs of CTOL, as well as the time savings for STOL and VTOL. Also the increased aircraft use has not been considered.

10. CONCLUDING REMARKS

The main arguments in favor of STOL and V/STOL systems equipped with fan lift engines are the following:

— Considerable improvement in short distance air traffic due to economy and convenience,

— lower capital investments compared with other systems,

— social-political reasons because of reduced influence on the environment.

It seems that aircraft with fan lift engines are the optimum solution for both STOL and V/STOL. The required state of the art has been reached in Europe. Nevertheless, there are considerable difficulties associated with convincing the public, the government officials and airline officials that VTOL really does have advantages as promised. For this reason, decisions are being delayed and the required funds for development are not being provided. If this situation persists, advances will only be made by a stepwise evolution. STOL would then represent a logical intermediate step, because STOL is simpler and can be operated more economically using the existing infrastructure than can be done with VTOL.

As the integration of western Europe progresses, it is important to make sure that the new STOL and VTOL systems will be oriented according to a European solution and not according to a national solution. This requires early cooperation of all affected agencies, in order to avoid duplication which would occur in an uncoordinated and separate development.

The enormous possibilities which STOL and VTOL offer to Western Europe should be pursued immediately. This would mean an aircraft such as shown in Figure 34 could be built within the next decade.

11. POSTSCRIPT

The author would like to thank the directors of Hawker Siddeley Aviation Ltd. for permission to publish this article. He thanks his colleagues in Hatfield for their support. The opinions and statements are those of the author and are not necessarily the official policy of the firm. /35

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